White Paper on Update aug-2001

Dense Wavelength Division Multiplexing (DWDM) and the Dickson Grating

R D Rallison, Ralcon corp, (Wasatch Photonics) email rdr@ralcon.com

1. Introduction

The origin of optical networks is linked to Wavelength Division Multiplexing (WDM) which arose to provide additional capacity on existing fibers. The advent of Dense Wavelength Division Multiplexing (DWDM) has fundamentally changed the economics of core optical networks. Consequently, virtually all operators of long distance fiber optic networks have implemented or are expected to implement DWDM.

DWDM employs different light wavelengths to transmit data parallel-by-bit or serial-by-character. It is a very crucial component of optical networks that will allow the transmission of data, voice, video-IP, ATM and SONET/SDH respectively, over the optical layer.

In today's high-end DWDM systems optimized for core networking, each wavelength (or channel) can operate at up to10 Gbps. Currently available systems support up to about 100 wavelengths per fiber, enabling a single fiber to carry several hundred gigabits of information. Systems supporting terabits per fiber have been demonstrated in laboratories and have been promised for commercial deployment.

Dec 2000 News:
* Claiming a world-best speed record for optical data transmission, researchers at Siemens have transmitted 7 Tbits/s over a single optical fiber using DWDM. That's the equivalent of over 100 million telephone calls or a billion pages of typed data per second. The demonstration was conducted by Siemens' Information and Communication Networks Group at the company's Advanced Optical Networks Laboratories. The researchers simultaneously transmitted 176 channels of 40-Gbit/s data over a 50-km fiber optic cable. The 40-Gbit/s channels, in turn, were produced by time-division multiplexing (TDM) using a prototype of TransXpress FOX, a multiplexer and regenerator system developed by Siemens.

2. Basic DWDM

The term "dense" WDM or DWDM, was once used to signify the use of more than eight wavelengths per fiber. The term DWDM is still generally used to reference high channel count systems. Long-haul DWDM systems take standard optical signals from "clients" such as SONET/SDH network elements, IP routers, or ATM switches, and convert each signal to a distinct, precise wavelength in the 1530- to 1610 nm range. These individual wavelengths are then combined (optically multiplexed) onto a single fiber. In the receive direction of the system, the reverse process takes place. Individual wavelengths are filtered from the multiplexed fiber and converted back to a standard SONET/SDH optical signal to the client. The complete DWDM system typically includes modules for each client interface in addition to equipment for multistage optical combining or splitting of wavelengths, amplification, and management/control, comprising several racks of equipment.

DWDM systems greatly simplify the expansion of network capacity. The only requirement is to install additional interfaces in the DWDM systems at either end of the fiber. The existing optical amplifiers amplify the new channel without the need for additional regenerators. The resultant cost savings will generally more than offset the cost of DWDM systems themselves. For this reason, virtually all core network operators are now deploying DWDM technology. Even new operators with a large number of fibers available will generally use DWDM to increase their capacity before lighting additional fibers.

The most important components of any DWDM system are transmitters, receivers, Erbium-doped fiber amplifiers, DWDM multiplexors and DWDM demultiplexors (mux/demux). Fig 1 shows the structure of a typical DWDM system.

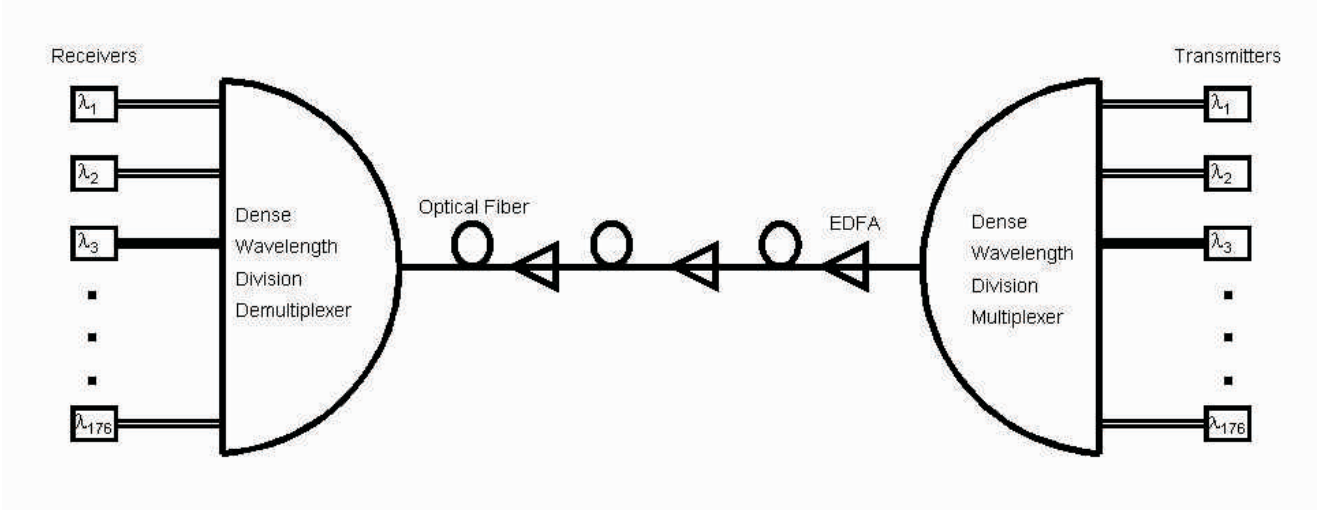

Fig.1 Block Diagram of a basic or typical DWDM System

2.1 Channel Spacing

The minimum frequency separation between two different multiplexed signals is known as the Channel Spacing. Since the wavelength of operation is inversely proportional to the frequency, a corresponding difference is introduced in the wavelength of each signal. The factors controlling channel spacing are the optical amplifier's bandwidth and the capability of the receiver in identifying two close wavelengths. These two parameters set the lower bound on the channel spacing, which ultimately restricts the number of unique wavelengths passing through the amplifier. Taking into consideration the above two factors, the international bodies have established a spacing of 50Ghz (.4 nm) to be the worldwide standard for DWDM. This effectively limits channel bandwidth to something under 40 Ghz

The multiplexer/demultiplexer then has to be able to easily resolve less than .4 nm and should be able to launch at least a hundred wavelengths into as many fibers with minimal losses. Fiber gratings have been useful in providing lower numbers of channels but will not work with tolerable losses as the number of channels rises. Bulk gratings would be a better choice for high resolution but when used at highly dispersive angles they typically fail to diffract both the S and P polarizations at the same efficiency or they do it only at a fairly low efficiency. There are a few special cases where this is not the case and one of them is the Dickson grating design, which has both high dispersion and high efficiency in both S and P polarizations. The efficiency is typically 95% for both all the way through C band and into L band.